REMARKS

Claims 1-7 and 11-18 are currently pending in the application; with claim 1 being independent. Claims 1-7 and 11-18 were pending prior to the Office Action. In this Reply, claims 1, 14 and 15 have been amended.

The Examiner is respectfully requested to reconsider the rejections in view of the amendments and remarks set forth herein. Applicants respectfully request favorable consideration thereof in light of the amendments and comments contained herein, and earnestly seek timely allowance of the pending claims.

Claim Objections

The Examiner objected to claim 4 because the recited "accelerated deuteron" lacks antecedent basis.

This objection is respectfully traversed. Since claim 1 now recites "a deuteron beam", "accelerated deuteron" in claim 4 has antecedent basis.

Accordingly, Applicants respectfully request that the claim objections be reconsidered and withdrawn.

Specification

The Examiner requested Applicants cooperation in checking the specification and correcting any errors.

Applicants have amended typographical errors in the specification. The amendments to the specification are supported by Figs. 7 and 8 (see the legends) which show μA (microamperes) as part of the units in the dose equivalent of solid angle of detector, as referring to the beam current.

The amendments to the specification were not made to overcome any objection or statutory rejection. No new matter has been added by way of the above amendments.

Claim Rejections – 35 USC §112

The Examiner rejected claims 14 and 15 under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which the applicant regards as the invention. In particular, the Examiner rejected claims 14 and 15 because the Examiner did not understand the meaning of "dose equivalent of neutrons" and the significance of the Sv/h/μA/sr units.

This rejection is respectfully traversed. Applicant has amended claim 14 to recite that "said material has a dose equivalent of neutrons for a deuteron beam of energy of 3.5 MeV equal to or smaller than $2.5 * 10^{-1}$ Sv/h/μA/sr" and claim 15 to recite that "the dose equivalent of neutrons for said material, when a deuteron beam of energy of 3.5 MeV strikes the material, is equal to or smaller than $2.5 * 10^{-2}$ Sv/h/μA/sr." The amendments to claims 14 and 15 are supported by Figs. 7 and 8 (see legends) and by the specification (page 12).

The dose equivalent of neutrons of a material for a deuteron beam of energy of 3.5 MeV represents the amount of neutrons emitted by the material when a 3.5 MeV deuteron beam strikes the material. The Sv/h/μA/sr units represent Sieverts/hour/microAmperes/steradian which are units that measure the dose equivalent of a material. The Examiner is directed to the description on page 12 of the specification for a detailed explanation of the dose equivalent of particles for a material which is subjected to an incident beam.

In view of the above, Applicant respectfully requests reconsideration and withdrawal of the 35 U.S.C. §112, second paragraph rejection of claims 14 and 15.

Claim Rejections – 35 USC §102 and §103

The Examiner rejected claims 1, 2 and 18 under 35 U.S.C. § 102(b) as being anticipated by US Patent 3,348,089 ("Thomas"). The Examiner rejected claim 3 under 35 U.S.C. § 103(a) as being made obvious by Thomas in view of US Patent 4,055,782 ("Hudson"). The Examiner rejected claims 4-7 and 11-13 under 35 U.S.C. § 103(a) as being made obvious by Thomas and Hudson further in view of US Patent 3,925,676 ("Bigham"). The Examiner rejected claims 16 and 17 under 35 U.S.C. § 103(a) as being made obvious by Thomas in view of US Patent 4,112,306 ("Nunan").

These rejections are respectfully traversed.

Applicants have amended claim 1 to recite:

"A particle beam accelerator comprising:

a vacuum chamber;

a magnet which generates a constant magnetic field in the vacuum chamber;

acceleration electrodes which generate an electric field in a direction perpendicular to the direction of the magnetic field generated by the magnet in the vacuum chamber; and

an extraction electrode which extracts charged particles accelerated in the vacuum chamber;

wherein a deuteron beam having an energy equal to or smaller than 3.5 MeV is generated;

wherein at least a part of surfaces exposed to the charged particles of the vacuum chamber, the acceleration electrodes, and/or the extraction electrode is made of a material including an element having atomic number larger than copper."

The amendment to claim 1 is supported by at least the description on page 9, line 23 to page 11, line 25, page 13 lines 11-24, and page 17 lines 1-13 in the specification.

To establish a *prima facie* case of anticipation or obviousness, the Examiner has the burden of meeting the basic criterion that the prior art must teach or suggest all of the claim limitations. Regarding this basic criterion, the Applicants submits that Thomas, Hudson, Bigham and Noonan do not and cannot disclose or suggest the features of the independent claim 1, as explained in detail below.

An explanation of the invention and its advantages is provided here to aid the Examiner in understanding the invention. "An object of the invention is to provide a particle beam accelerator reduced in size and weight further" as explained on page 4, lines 16-17 of the specification.

The background and context of the invention, and the drawbacks of the prior art solved by the invention are explained as follows. In a positron emission tomography (PET) facility, ^{15}O isotope having a short half life of two minutes is generated by a cyclotron, and a reagent or reagents for a medical examination is prepared with the ^{15}O isotope. In a conventional procedure, the prepared radioactive reagent (gas) is transported to a PET examination room and is

administered to a subject being examined. On the other hand, in a nuclear reaction to generate ^{15}O from ^{14}N, a sufficient amount of reagent can be synthesized with ^{15}O generated at the acceleration energy of about 3.5 MeV (page 2, line 17-22 in the specification). A cyclotron for creating a deuteron beam of 3.5 MeV can be made to have a relatively smaller size. Until Applicants' invention, such small cyclotrons were used in four facilities to generate a deuteron beam of 3.5 MeV, but they were placed in PET facilities wherein a large cyclotron was already placed, since it was necessary to have a radiation shield structure similar to previous cyclotrons because many neutrons are generated during irradiation of a beam. That is, these smaller cyclotrons that existed before Applicants' invention were not engineered to be reduced in size and weight, as they created significant amount of radiation harmful to humans, especially neutrons, and a special shielding body or a device was necessary for the cyclotrons to block harmful radiation and especially neutrons (see page 3 line 1 –page 4 line 11 of the specification for additional explanations).

The inventors developed a new examination procedure with ^{15}O isotope carried out in a very short time (please refer, for example, to a copy of the front page of WO 2006/043674, attached herein), which made it possible for such rapid examination procedure to be implemented in general medical organizations (having about 100 beds, for example) dealing with brain infarction patients. In practical operations using such examination procedures, it would be necessary to place a cyclotron in a general medical facility for creating ^{15}O of short half-life, and to provide a shielding structure for neutrons irrespective of the size of cyclotrons. <u>In other words, a big shielding structure would be necessary, and the building of the hospital facility would have to be modified to set such a cyclotron requiring shielding.</u>

On the other hand, the particle beam accelerated of the present invention can suppress creation of neutrons essentially without a shielding structure of a prior art concrete wall. This represents an important contribution for building a small-size lightweight cyclotron. The cyclotron of the present invention has a very compact size; consequently, it needs a small installation space. If the compact cyclotron of the present invention is dedicated to generation of ^{15}O isotope, for example, the cyclotron implementing the above-mentioned examination procedure with ^{15}O isotope can be placed in a medical facility easily and without a large scale

reconstruction of the hospital facility, since a concrete shielding wall having a typical thickness of 1.8 meter or more (as typically needed in conventional large or small cyclotrons) is not necessary for the small cyclotron of the invention. The compact cyclotron of the present invention can be dedicated to generation of other isotopes as well, besides the ^{15}O isotope, and can be easily placed and used in a medical facility not customized with heavy wall shielding, for use in various medical processes.

Neutrons, which are produced in conventional particle beam accelerators, are the most difficult to shield among the particles generated by secondary radioactivity. The fact that neutrons are generated for almost all nuclides makes this problem even worse. For this reason, in a conventional particle accelerator, a thick layer of water, paraffin or the like is used for shielding neutrons.

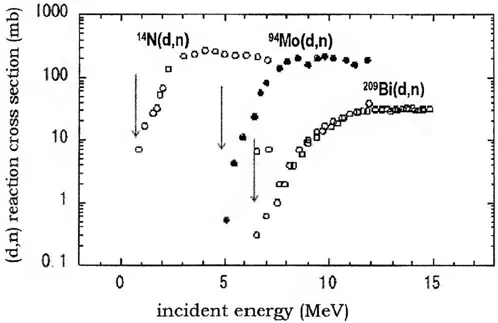
The accelerator of the present invention reduces secondary radiation, such as neutrons, in a different way, which makes it possible to decrease the size and weight of a cyclotron significantly. In the present invention, in order to decrease the size and weight of a cyclotron, the energy of a deuteron beam is set to 3.5 MeV or lower, and at least a part of the surfaces to be exposed to the charged particles and included in the main components in the particle generator is made of a material including an element having atomic number larger than copper, as claim 1 recites. Thus, the generation of neutrons can be suppressed, as further explained below, and this contributes to a decrease in size of a shielding body that would otherwise have been necessary to suppress leakage of neutrons to the outside. In the energy range higher than 3.5 MeV which was the domain of prior art particle accelerators such as those described in the Thomas, Hudson, Bigham and Noonan references, reduction to such a very small accelerator size cannot be realized.

The range of acceleration energy of a deuteron beam is set to 3.5 MeV or lower in the present invention, because a sufficient amount of a reagent can be synthesized with acceleration energy of 3.5 MeV or lower, and this energy range is essential for providing a very compact cyclotron which could be dedicated to ^{15}O gas to be used in a PET facility.

With beam irradiation, radiations of very short life and many neutrons are generated. Suppression of the neutron generation in the present invention, with a material including an element having a high atomic number is explained below, for Examiner's convenience.

A nuclear reaction has a threshold for the reaction. An incident nucleus and a target nucleus repel each other because both have positive charges. If an accelerated incident nucleus such as a deuteron has kinetic energy exceeding the repulsive force (the Coulomb barrier) and comes very near the target nucleus in the range where the interaction of nuclear force appears as a very strong attractive force, the incident nucleus collides with the target nucleus, and a nuclear reaction occurs. Because the repulsive force becomes stronger with increasing charges of the two nuclei, higher incident energy is needed for a collision between heavier nuclei. However, if a material of a component with which the incident nucleus collides is selected so that the energy of the incident nucleus becomes smaller than the Coulomb barrier of the material, the generation of neutrons can be suppressed towards the minimum limit.

For example, as shown below in a graph on reaction cross section of three elements plotted against incident energy, the nuclear reaction $^{14}N(d,n)^{15}O$ occurs at deuteron energy of 2-3 MeV and generates neutrons, while in a collision with a heavier nucleus target, a nuclear reaction occurs at a higher acceleration energy. For example, for molybdenum (^{91}MO), no nuclear reaction happens even at incident energy of 5 MeV and does not generate neutrons. For example, refer to a database in the Internet, at http://www.nndc.bnl.gov/exfor/exfor00.htm and http: //www.nndc.bnl.gov/ exfor/servlet/X4sSearch5 for further experimental data.



The present invention is based on the physical phenomenon which occurs only when a nucleus with low energy of 3.5 MeV or lower is incident, and generation of neutrons is prevented completely for elements having high atomic numbers. (In the graph of Fig. 7 in the application, the linear equivalent ratio of heavy nuclei becomes low due to the Coulomb barrier mentioned above.) In concrete, a material having high Coulomb barrier for incident energy of 3.5 MeV or lower is selected for an internal wall in a particle accelerator, so as to suppress the nuclear reaction and the generation of neutrons essentially. For a beam current of 1 μA, for example, the linear

equivalent dose on irradiation is $2.5*10^{-1}$ Sv/sr or lower (Fig. 7). Thus, generation of neutrons on operation can be suppressed, so that even if a physician and a patient for a medical examination are present in a room adjacent to the cyclotron, the amount of exposure to active radiations can be suppressed below the regulated limit. Therefore, the shielding body for suppressing leakage of neutrons has a much more compact size and a much lower weight. As explained in page 15, lines 1-20 in the specification, a portion at which the low energy beam or scattered particles collide

can be made of a sheet having thickness of 1 mm or lower of a material including an element having atomic number larger than copper.

Previously, it was considered difficult to prevent generation of radioactivity on beam irradiation especially when a large amount of neutrons were generated, and to provide a very small cyclotron. According to the present invention, it becomes possible to suppress creation of neutrons in the particle beam accelerator. Thus, it becomes possible to place a cyclotron in a part of a PET examination room or in an adjacent room, and this makes it possible to perform a PET examination in many medical facilities.

The references cited by the Examiner do not disclose a particle beam accelerator in which radioactive radiation such as neutrons is suppressed by generating a deuteron beam having an energy equal to or smaller than 3.5 MeV and by having at least a part of surfaces exposed to the charged particles of the vacuum chamber, the acceleration electrodes, and/or the extraction electrode to be made of a material including an element having atomic number larger than copper.

An accelerator (cyclotron) disclosed in Thomas (US 3,348,089) is provided to generate an output ion beam which is many times more intense that that obtainable with a conventional accelerator. Therefore, Thomas does not deal with low acceleration energy accelerators as claim 1 recites. A neutron source disclosed in Bigham is provided to generate a neutron beam, which is against the goal of the accelerator of claim 1. A neutron irradiation therapy machine of Nunan also generates a beam of high energy neutrons. Therefore, they are not relevant to the claimed accelerator, which suppresses generation of neutrons. The tungsten sheet of Thomas, the gold backing of Bigham, and the tungsten shield of Nunan would generate neutrons at nuclear reactions at a high acceleration energy. The ions disclosed in Hudson in an ion source for a cyclotron are not yet supplied to the vacuum chamber. Thus, Hudson is not relevant to the accelerator recited in claim 1, because the ion source parts of Hudson are not "a part of surfaces exposed to the charged particles of the vacuum chamber" as claim 1 recites.

Therefore, the references do not disclose or suggest:

"A particle beam accelerator comprising:

a vacuum chamber;

a magnet which generates a constant magnetic field in the vacuum chamber;

acceleration electrodes which generate an electric field in a direction perpendicular to the direction of the magnetic field generated by the magnet in the vacuum chamber; and

an extraction electrode which extracts charged particles accelerated in the vacuum chamber;

wherein a deuteron beam having an energy equal to or smaller than 3.5 MeV is generated;

wherein at least a part of surfaces exposed to the charged particles of the vacuum chamber, the acceleration electrodes, and/or the extraction electrode is made of a material including an element having atomic number larger than copper"

as claim 1 recites.

For all of the above reasons, taken alone or in combination, Applicants respectfully request reconsideration and withdrawal of the 35 U.S.C. §102 and §103 rejections of claim 1 and claims 2-7 and 11-18 depending from claim 1.

Conclusion

In view of the above amendments and remarks, this application appears to be in condition for allowance and the Examiner is, therefore, requested to reexamine the application and pass the claims to issue.

Should there be any outstanding matters that need to be resolved in the present application, the Examiner is respectfully requested to contact Corina E. Tanasa, Registration No. 64,042, at telephone number (703) 208-4003, located in the Washington, DC area, to conduct an interview in an effort to expedite prosecution in connection with the present application.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional fees required under 37 C.F.R. §§ 1.16 or 1.17; particularly, extension of time fees.

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Respectfully submitted,

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